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Autonomous Healthcare Transportation: A Human-Centered Approach to Delivering Care

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Autonomous Healthcare Transportation: A Human-Centered Approach to Delivering Care

by

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Report

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

Master of Fine Arts

The University of Texas at Austin

May 2018

Acknowledgements

Thank you to the many people who supported my work over the last two years. I would like to extend a special thanks to my report reader Jiwon Park, who provided an abundance of thoughtful writing and design critique throughout this journey. Thank you to Carma Gorman, who offered additional insight into how to be a better writer. Thank you to my classmates Ajinkya, Ekin, Jean, Juliana, Subodh, and Kira for keeping me on my toes. In addition, I would like to thank my coworkers from the Design Institute for Health, who provided invaluable feedback and inspiration for this research.

Any errors or omissions in this report are my own.

Abstract

Autonomous Healthcare Transportation: A Human-Centered Approach to Delivering Care

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Millions of Americans—especially those with limited mobility, vision, cognition, and financial resources—miss or delay healthcare appointments each year due to inadequate transportation. Although there are a handful of options for non-emergency medical transportation, they are expensive, complicated to use, and often deliver a poor patient experience, especially for those who could benefit most from these services. Using human-centered design methods and building on existing research, healthcare trends, and 20 interviews with target users and subject matter experts, this paper proposes a set of speculative autonomous vehicles and service concepts to increase access to healthcare through a patient-centered experience grounded in preventative care. The goal of this paper is to provoke cities and companies to utilize autonomous vehicles to provide more convenient and cost-effective forms of NEMT to those in greatest need and to serve as an early guidepost for exploring design opportunities for autonomous healthcare transportation.

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Introduction: Current Challenges in Healthcare Transportation

The current state of non-emergency medical transportation (NEMT) in the United States is bleak. Millions of people forgo necessary medical care because they do not own a vehicle, are unable to drive, cannot afford the cost of public or private transportation, or have limited time.[1] These barriers consequently lead to unnecessary emergency room visits, costly hospitalizations, avoidable surgeries, and reduced quality of life—yet there are emerging technologies that can help alleviate some of this burden.[2] Building on the growing trend of public-private transportation partnerships and the commercial future of autonomous vehicles, I have used human-centered design methods to develop a set of health transportation vehicle concepts and a service system that takes advantage of the imminent emergence of autonomous vehicles.[3] The long-term goal of this work is to offer an early guidepost for states and companies exploring design opportunities for autonomous vehicles—with an explicit focus on NEMT.

Although federal legislation requires states to provide NEMT for transportation-disadvantaged populations such as the elderly, the disabled, and the economically disadvantaged (at a cost of around $3 billion per year), most transportation programs fall short of solving the problem.[4] Common problems with existing solutions—many of which are delivered by third parties who contract with states to provide NEMT—include poor vehicle tracking and data collection, long wait times, long scheduling lead times, inadequate patient complaint resolution, and poor communication between patients and transportation providers.[5]

Recognizing the benefits of providing more reliable, convenient, and cost-effective NEMT, states and healthcare systems have started to explore new transportation options

through partnerships with private transportation companies to adapt existing for-profit on-demand ride hailing services such as Uber, Lyft, and similar companies to provide NEMT.[6] Unfortunately, these technology companies often provide generic ride hailing services for a population that needs a customized transportation solution that caters to a unique set of patient barriers, such as limited mobility, vision, and cognition. In addition, states have found it challenging to manage payments or reimburse patients for rides taken for NEMT. Many patients, especially those who could benefit most from these services, have limited familiarity with ride-hailing technology and may not have smartphones or credit cards, which are often required to use ride-hailing apps.[7]

As the commercial introduction of fully autonomous vehicles potentially looms just 5 to 10 years away, city governments and private organizations will benefit from exploring new opportunities for designing an innovative health transportation system that harnesses this new technology—while also reducing costs and improving community health.[8] These benefits may include the ability to deliver healthcare at times and locations most convenient to patients, to facilitate transport for those with limited mobility, cognition, and vision; and to test new ways of delivering preventative care and health-related items, such as medical equipment, groceries, and medication.

Using human-centered design methods and tools, this report identifies opportunities and proposes new service concepts to improve NEMT in a future when autonomous vehicles are common forms of transportation. My aim is to provoke cities and companies to design and mobilize autonomous vehicles to provide more convenient and cost-effective forms of NEMT to those in greatest need, particularly children, the elderly, and those with limited vision, cognition, and mobility.

Research Methods and Process

The design process for this project was divided into four main phases: discovery, insights, ideation, and design. Each of these phases used different tools, but they were all grounded in human-centered design, which takes human perspectives into consideration at each phase of the design process. The following section provides additional details on the four main research methods and types used throughout this project.

Literature Review

I began my design process with a review of existing literature on non-emergency transportation technology and service programs and existing barriers to transportation, especially for the uninsured, underinsured, and those with limited mobility. Next, I reviewed other automotive trend reports for autonomous vehicles and emerging technologies to better understand what types of features might be available in the future and how they might be used to benefit a diverse patient population. I also reviewed existing research on evolving trends in healthcare to understand how autonomous transportation might fit into the future framework of healthcare provision in the United States.

Interviews

After reviewing existing research on NEMT and related technologies, I completed a series of informal conversations with nine subject-matter experts, such as registered nurses, social work case managers, and transportation providers—as well as eleven target users in Austin, Texas and Madison, Wisconsin—to explore existing pain points, desires, and latent needs of both patients and providers within the existing healthcare transportation system.

USER PERSONAS

Based on conversations with target users and a review of population demographics in Austin, Texas, I developed three user personas to represent different use cases. I then shared user characteristics with design workshop participants to help guide the ideation of speculative vehicle features and service concepts. In addition to general background information on each user, the personas describe each individual's goals, frustrations, and knowledge and abilities as related to the existing transportation system.

DESIGN WORKSHOPS

I conducted two design workshops, the first with three fellow students in the MFA design program at the University of Texas at Austin, and the second with employees from the Design Institute for Health (a partnership between the University of Texas at Austin College of Fine Arts and Dell Medical School) to share my initial insights from the target user interviews and brainstorm potential vehicle features and service concepts. I then reviewed, consolidated, and refined content from these workshops into groups of speculative concepts.

Research Insights

From the research I conducted, I derived the following insights that I believe should shape the design of autonomous NEMT vehicles and systems:

EMERGING TRENDS IN HEALTHCARE AND HOW THEY MAY INFLUENCE NEMT

The Shift to Value-Based Care Will Provide Economic Incentives to Improve NEMT

The United States healthcare system will continue to move from a fee-for-service payment model to one based on providing care at lower cost and higher quality.[9] This shift in how we pay for care will open new venues to address individual needs through a holistic approach to patient-centered care. This includes the provision of preventative services with novel transportation models, such as managing chronic conditions, improving treatment adherence, and delivering preventative care tailored to patients with limited mobility.

The Social Determinants of Health Will Reignite Focus on the Value of NEMT

Healthcare organizations and communities will refocus on the social determinants of health—the factors that affect patient and community health beyond the typical healthcare setting.[10] These areas include education, employment, family and social supports, housing instability, food insecurity, and transportation. The greater emphasis of these factors will encourage federal, state, and local governments to explore the economic value derived from facilitating access to healthcare for those with limited access to transportation.

New and More Useful Health Data Can Be Gathered from Individuals In-Transit

Data from passive sensors, wearable health devices, and the expanding Internet of Things (IoT) will be used to treat and monitor patients in new ways.[11] As the benefits of sharing data across the healthcare system grows, new methods of collecting and sharing these data will continue to evolve. Vehicle manufacturers will benefit from exploring novel ways of including these types of health sensors into healthcare transportation vehicles as the role of NEMT expands.

Patients Will Gain Greater Control Over How and When They Get Healthcare

Patients and caregivers will gain more self-sufficiency as they become increasingly informed and involved in their treatment plans and care. These developments may lead to new venues for patients to get care and gain autonomy outside of the traditional clinical healthcare system. Once such venue may be the vehicle, which could allow the current model of care (patient coming to the provider) to be inverted, letting patients access care in a venue with greater mobility, at a time and in a venue that fits their schedule and the needs of those who care for them.[12]

Data Privacy Will Grow in Importance as the Collection of Patient Data Expands

As health data proliferates inside and outside of the traditional healthcare setting, there will be an increasing need to maintain confidentiality of this information.[13] The focus on privacy will multiply as more data is collected and shared across an expanding network of healthcare providers and systems. These changes will require more transparency among healthcare providers regarding what data is collected, how it is used, and who has access to it. As more technology moves into vehicles, NEMT providers will benefit from keeping these issues top of mind when designing and implementing new service features.

USER INSIGHTS

Conversations with healthcare and transportation providers and target users of non-emergency medical transportation generated a number of insights into the existing pain points, desires, and latent needs of both patients and the existing healthcare transportation system. These conversations aided with the formation of a set of high-level findings related to today's individual experience, associated vehicle characteristics, and related issues with NEMT.

One: Patients value in-person and in-vehicle assistance for both the physical benefits of getting from their door to a vehicle and the service experience that on-board staff and other riders provide.

A personal touch is key. Patients with limited mobility, vision, and cognition and medically complex cases benefit from the hands-on service that transportation staff provide by helping them get from the door of their home to the door of a vehicle. While in transit, these patients also appreciate a more direct personal and social connection to transportation staff or other riders who may have relevant system knowledge to share with others in the vehicle.

Two: Clear communication drives patient comfort and confidence while in transit, but it's often siloed between a series of disparate actors throughout the transportation journey.

Patients and healthcare providers seek clear information before, during, and after healthcare encounters, including information about the transit experience. This might involve details about what is going to happen, how long it might take, or where and when the next healthcare encounter may occur. Unfortunately, this information is often not

available or not shared seamlessly, which harms the patient experience and the day-to-day logistics for healthcare providers and local transportation services.

Three: Patients often receive complex yet essential health information during condensed encounters with healthcare providers, which can be overwhelming to patients focusing on transportation challenges.

Patients receive an abundance of information towards the end of most healthcare encounters, particularly when meeting face-to-face with providers and at discharge. This spike in information density often coincides with competing demands related to transportation, which can lead to missed communication opportunities and lack of understanding between patient and provider. While providers sometimes provide follow-up calls to patients, many individuals are difficult to reach due to a lack of consistent cell phone service or insecure housing.

Four: Emergency medical transportation provides a highly visible, near immediate transportation solution for some patients who may benefit from a more consistent yet lower-tier level of medical care.

Typical emergency vehicle response time is 5-7 minutes, whereas non-emergency medical transportation often requires prior authorization from insurers and is typically scheduled a minimum of 2-5 days in advance. Many patients faced with the decision of how to quickly get healthcare when they don't know where else to turn choose to call emergency medical services, which sometimes turns out to be too little care too late—or more care than they need. Given these constraints, patients may benefit from alternate healthcare transportation options that deliver the correct level of transport on-demand.

Five: Patients rarely travel alone; they often require adaptable solutions to accommodate medical equipment, family members, caregivers, and mobility assistance devices that some transportation options do not offer.

Patients traveling to and from medical appointments, follow-up visits, and long-term care facilities often need assistance transporting additional equipment. These items—such as oxygen tanks, shower chairs, child car seats, and strollers—make it difficult to access regular public transportation routes or ride-hailing services, especially when patients suffer from pain or face additional physical mobility limitations. Although some vehicles provide options to store and transport these items, many services lack flexible vehicles that can adapt to patient needs in real-time.

Six: Existing non-emergency medical transportation solutions are restricted to A to B routes, even though patients often require multiple stops to accommodate other health needs.

Patient journeys are rarely constrained to a linear pick-up and drop-off point with no stops in between. Depending on the individual, they may visit multiple locations before getting to an appointment and when returning home or to a different location, such as work, a child's day care, the grocery store, or a local pharmacy. Existing non-emergency medical transportation solutions are unable to accommodate these needs, which may adversely affect patient satisfaction, medication adherence, and long-term health outcomes.

USER PERSONAS

Building on conversations with target users and subject-matter experts, I developed three user personas to help guide the development of design concepts. These fictional user

personas were primarily used to test the user fit of vehicle features, vehicle types, and service concepts as they emerged during the design process. Abbreviated versions of these personas were also used to illustrate ideal target users for each speculative service concept when sharing ideas with outside reviewers of this work.

Persona One: Rachel

Diabetic mother who is responsible for taking her two-year-old son to regular medical checkups and screenings.

Primary Goals: To quickly get to medical appointments and screenings, to save money on transportation around the city, to help her two-year-old son and herself get and stay healthy.

Frustrations: Absence of convenient appointment time during working hours, uncertainty of appointment duration and follow-up, lack of storage space for childcare items including stroller, car seat, and diaper bag.

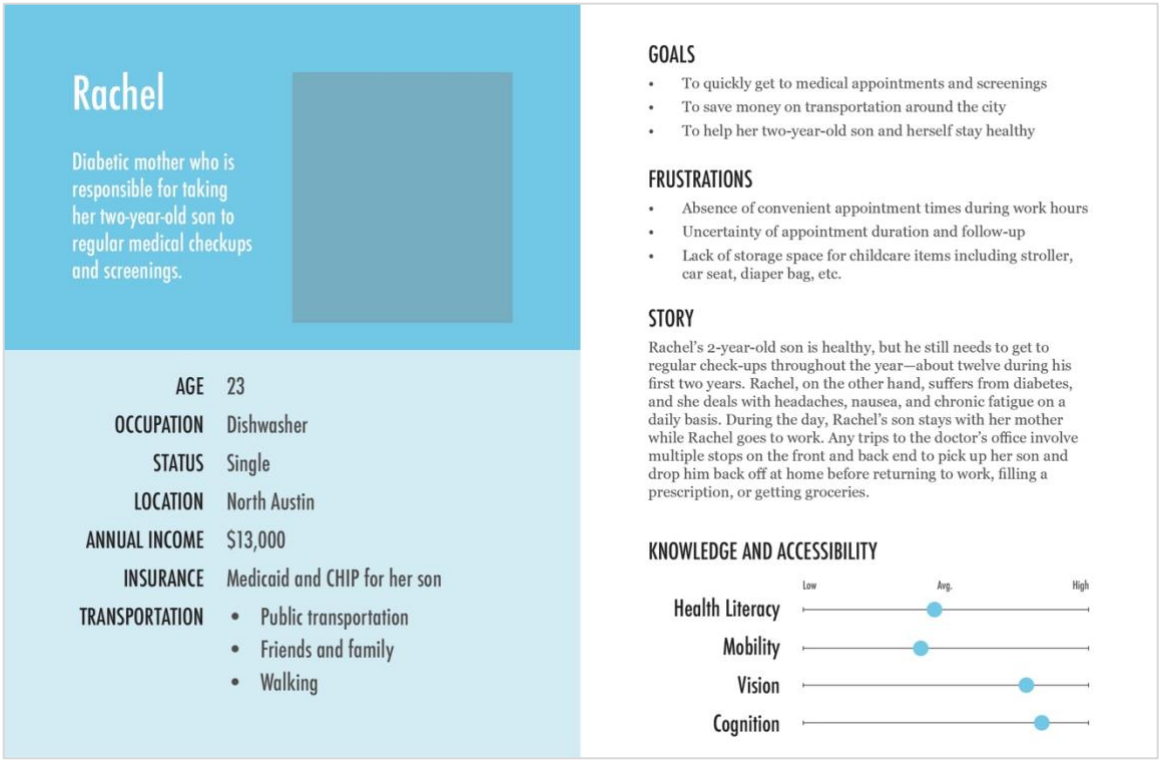

Figure 1: Persona One—Rachel

Persona Two: Isabella

Elderly woman with memory, vision, and mobility limitations who lives with her husband in a rural area.

Goals: To remain living in her home with her husband, to understand her medical conditions and future treatment, and to spend more time with her family and friends.

Frustrations: Fear of getting lost while going to an appointment, finding the specific building, and returning home; uneasiness when traveling with strangers; anxiety with traveling on major highways at high speeds.

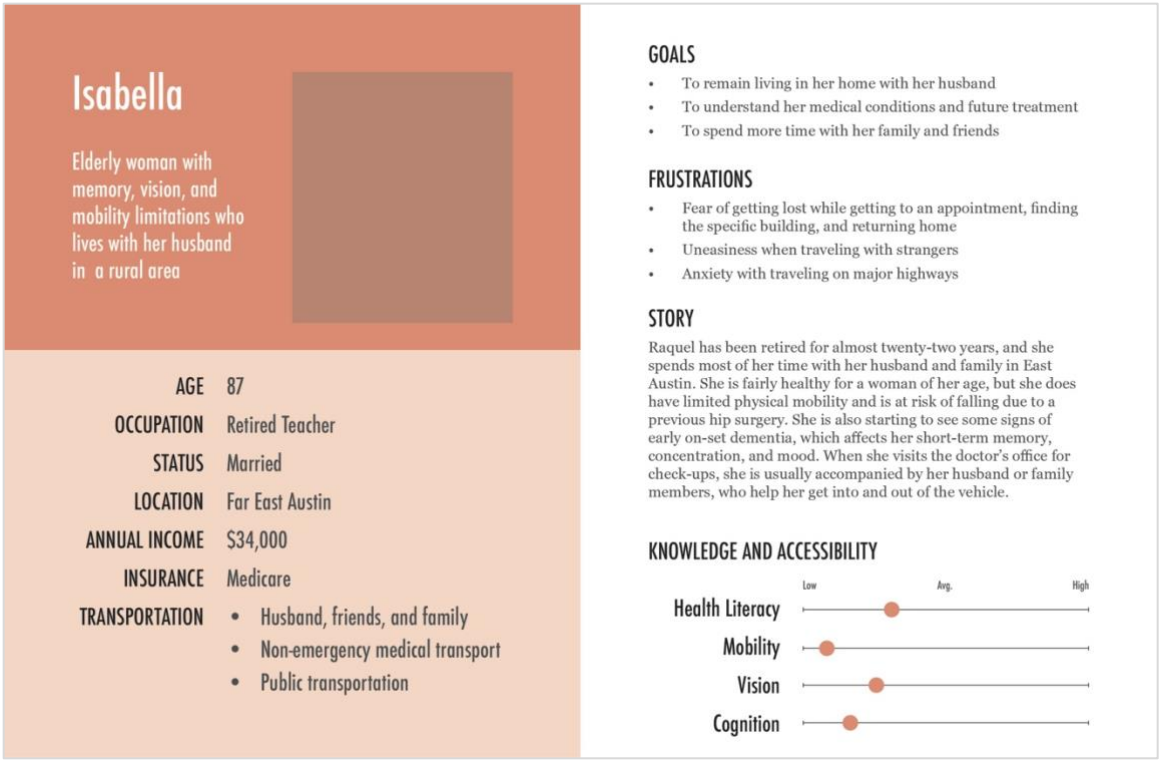

Figure 2: Persona Two—Isabella

Persona Three: Henry

Disabled veteran with back pain, a knee injury, and PTSD who has frequent visits to the hospital for chronic pain.

Goals: To gain personal autonomy getting to and from the doctor, to understand and reduce the prescriptions he is taking, to have less-frequent trips to the VA for chronic conditions.

Frustrations: Communication breakdowns within the healthcare system and between his regular healthcare providers; lack of flexibility in routes for medical transportation, excess noise and activity in public transportation that aggravates his PTSD

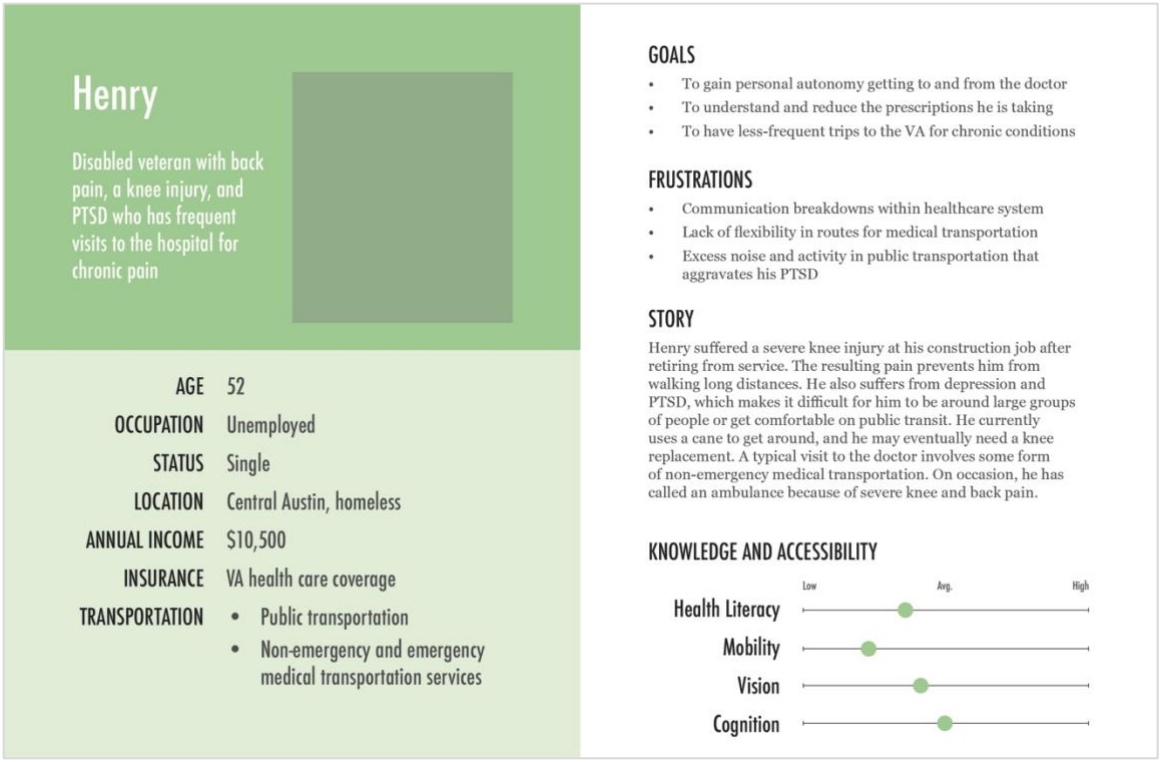

Figure 3: Persona Three—Henry

Design Proposal

The design proposal section is divided into two main parts: Design Principles, a set of six principles intended to guide and inspire the design of autonomous vehicles for healthcare transportation; and Vehicle Design, a high-level overview of proposed vehicle features, vehicles types, and services based on insights from design research.

DESIGN PRINCIPLES

Derived from insights gained from target user research and conversations with experts in the fields of healthcare and patient transportation, these design principles were created to guide development of the autonomous healthcare transportation project. They served three key purposes: 1) To act as guardrails for brainstorming during the design workshops, 2) To evaluate concepts in relation to real patient needs during synthesis (e.g. does x concept meet the needs and requirements of y users?), and 3) To serve as a guidepost for cities and private companies exploring opportunities for human-centered autonomous healthcare transportation.

Make Spaces Flexible

Provide adaptable services and spaces that allow patients, families, and caretakers to feel comfortable and accounted for throughout the journey.

Champion Privacy

Ensure the privacy of patients' health data; let them know who can see this data, why it's used, and how it can help them get and stay healthy.

Provide Reassurance

Offer reassurance for both patients and providers throughout the healthcare journey, informing key care team members (doctors, nurses, case managers, caregivers, family members) when, why, and how patients get care.

Deliver On-Demand

Connect the community to healthcare quickly, including community clinics, pharmacies, and other health services, such as social recreation and fitness.

Maintain a Human in the Loop

Keep a human in the digital healthcare loop to provide flexible patient options and deliver a personalized, hands-on approach to healthcare transportation—either in person or virtually.

Serve as Interpreter

Serve as interpreter of a complex health system, reinforcing patient education, offering a venue for dialog, and coordinating messaging across organizations.

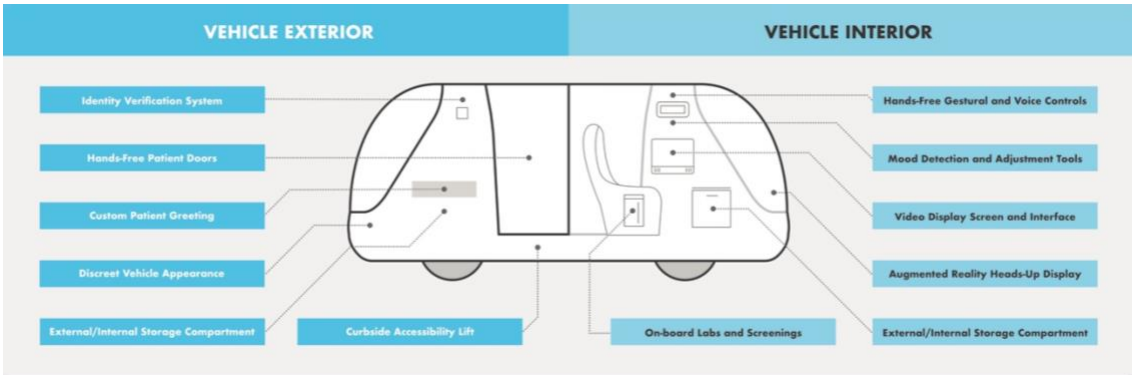

Figure 4: Overview of Vehicle Exterior and Interior

VEHICLE DESIGN

Following the primary research phase and design workshops, I reviewed, synthesized, and consolidated design concepts into three main categories: vehicle features, vehicle types, and vehicle services. Each of these groups was then broken down into smaller subgroups to determine which concepts most clearly aligned with target user research insights, design principles, and the formation of a comprehensive health transportation service system grounded in preventative care. Based on this review, I finalized twelve essential vehicles features, four vehicle types, and four potential use cases, each of which are described below.

Vehicle Features

Vehicle Exterior

This section contains a set of vehicle features and their associated uses and benefits for a diverse patient population. This is not meant to be an exhaustive list of all concepts developed during the research phase. Instead, it proposes a set of recommended vehicle features beneficial to the creation of a comprehensive health transportation system grounded in a human-centered approach to comprehensive healthcare.

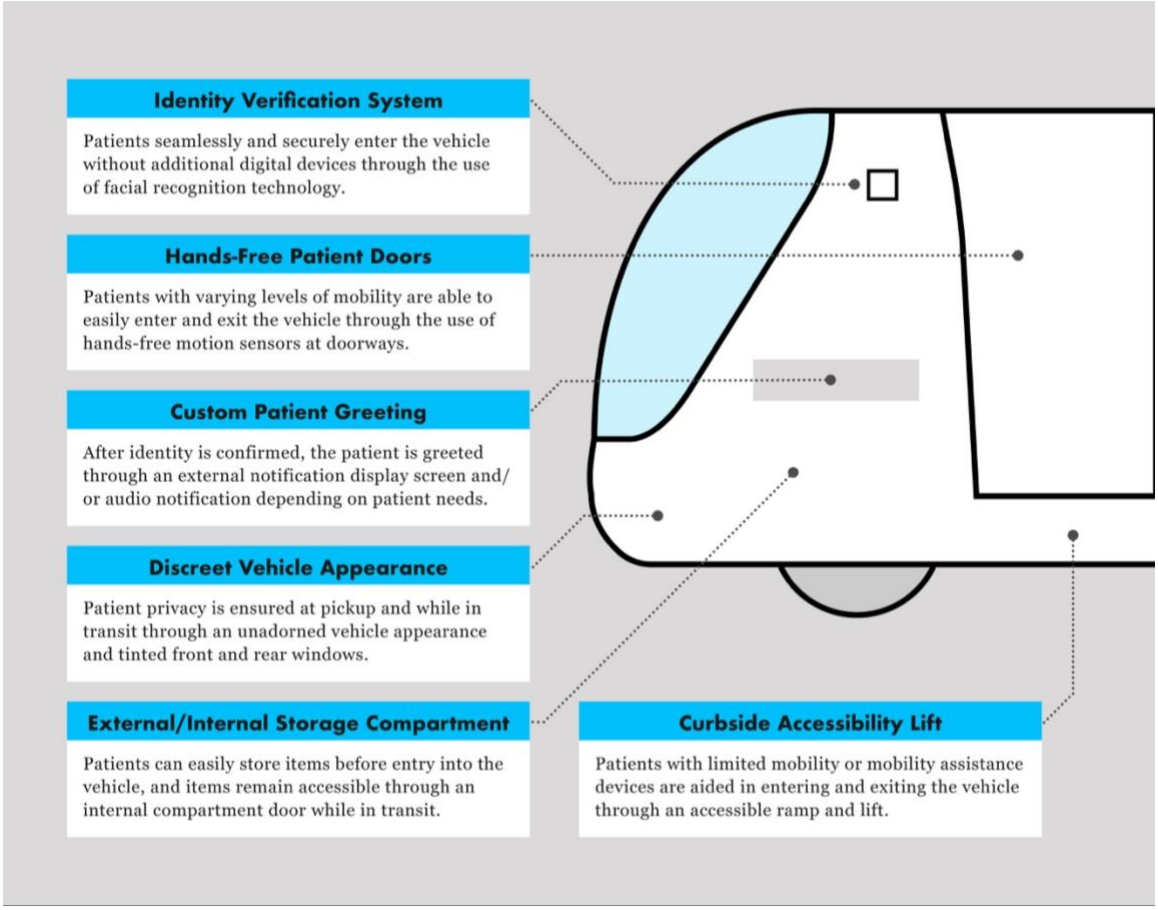

Figure 5: Exterior Vehicle Features

Identity Verification System

Patients can seamlessly and securely enter the vehicle without additional digital devices through the use of facial recognition technology.

Hands-free Patient Doors

Patients with varying levels of mobility are able to easily enter and exit the vehicle through the use of hands-free motion sensors embedded in the vehicle.

Custom Patient Greeting

After patient identity is confirmed, patients are greeted through an external notification display screen and/or audio notification depending on patient needs.

Discreet Vehicle Appearance

Patient privacy is ensured at pickup and while in transit through an unadorned vehicle appearance and tinted front and rear windows.

External/Internal Storage Compartment

Patients easily store items before entry into the vehicle, and items remain accessible through an internal vehicle compartment door while in transit.

Curbside Accessibility Lift

Patients with limited mobility or mobility assistance devices are aided in entering and exiting the vehicle through an accessible ramp and lift.

Vehicle Interior

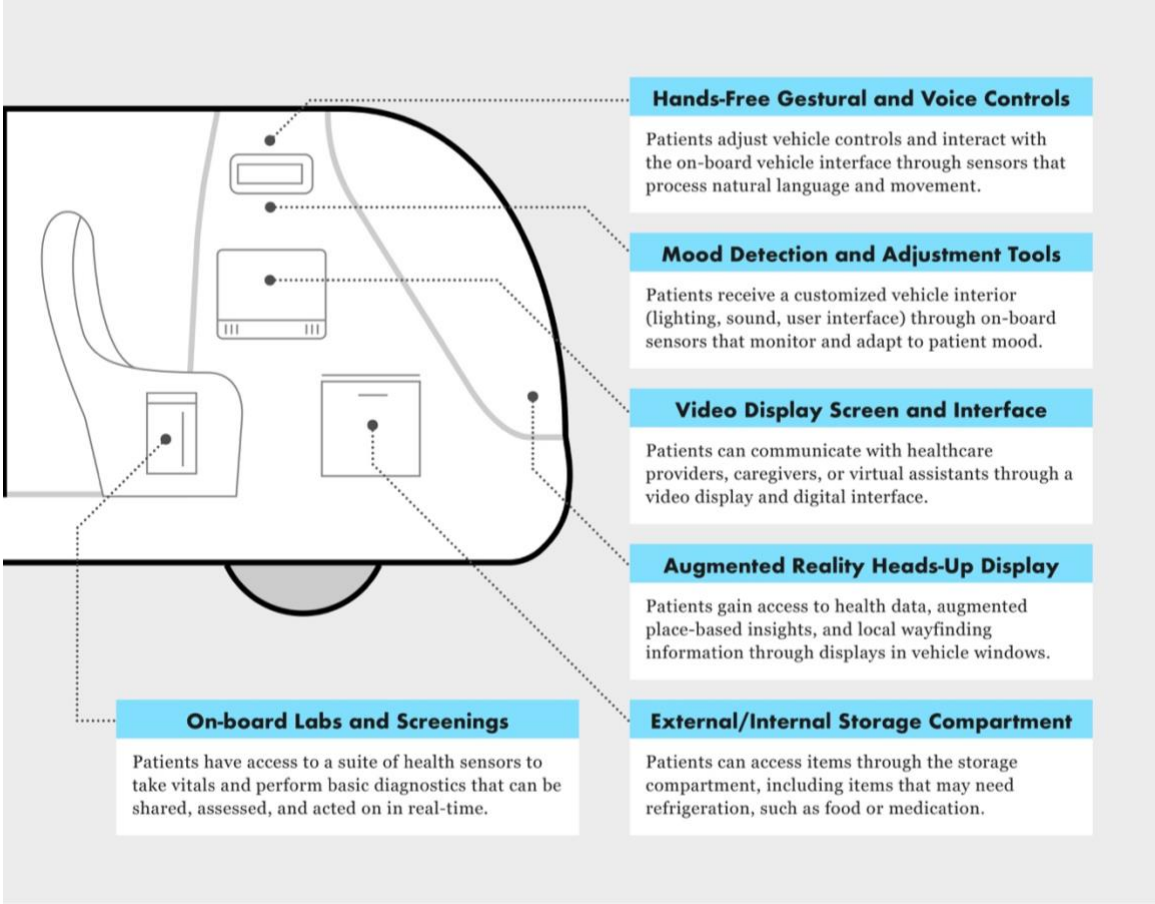

Figure 6: Interior Vehicle Features

On-board Labs and Screenings

Patients have access to a suite of health sensors to take vitals and perform basic diagnostics that can be shared, assessed, and acted on in real-time.

Hands-Free Gestural and Voice Controls

Patients adjust vehicle controls and interact with the on-board vehicle interface through sensors that process natural language and movement.

Mood Detection and Adjustment Tools

Patients experience a customized vehicle interior (lighting, sound, user interface) through the use of on-board sensors that monitor patient mood.

Video Display Screen and Interface

Patients communicate with healthcare providers, caregivers, or virtual assistants through a video display and digital interface.

Augmented Reality Heads-Up Display

Patients gain access to health data, augmented place-based insights, and local wayfinding information through displays embedded in vehicle windows.

External/Internal Storage Compartment

Patients access items through the internal/external storage compartment, including items that may need refrigeration, such as food or medication.

Vehicle Types

The four main vehicle types grew out of a review of existing vehicle technology, patient needs, and brainstorm sessions during the two design workshops. Taken together, they offer a suite of services ranging from delivery to curbside treatment and triage to population-level health monitoring and epidemic control. The general size and features of each vehicle is outlined below.

Healthcare Delivery Pod

Small vehicle that provides on-demand delivery of healthcare-related items such as prescriptions, groceries, medical equipment, and supplies.

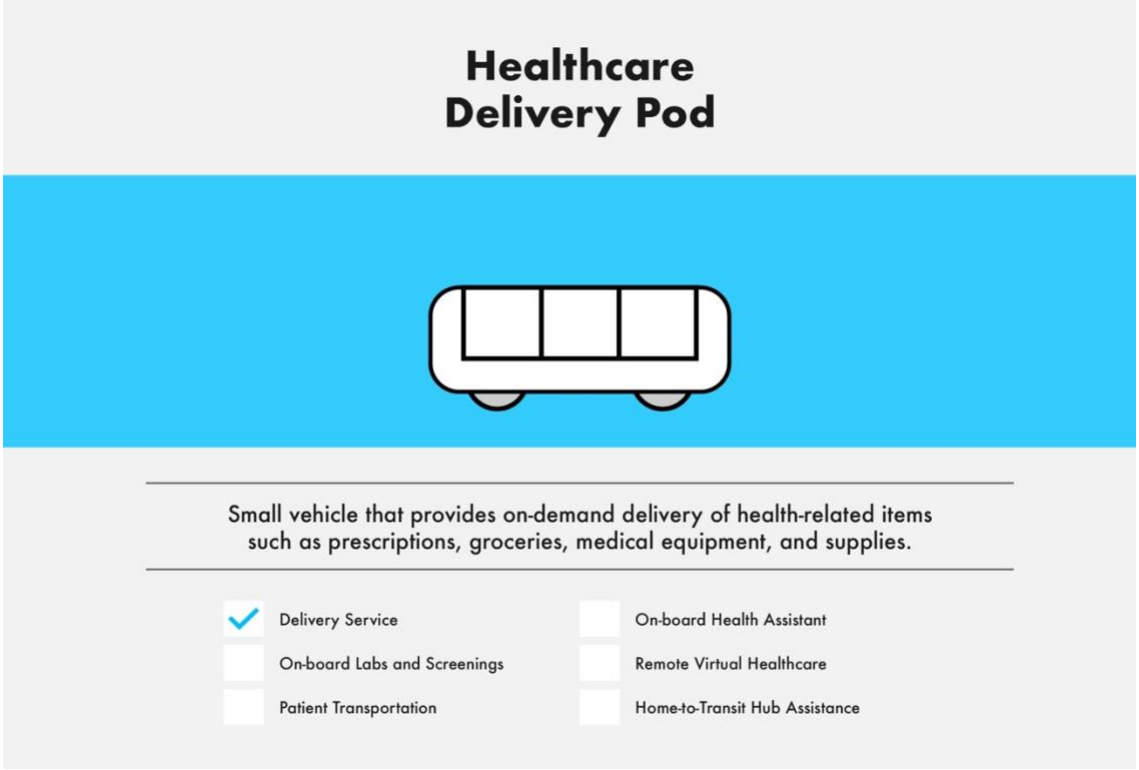

Figure 7: Vehicle Type: Healthcare Delivery Pod

Community Health Kiosk

Mid-sized vehicle that provides curbside and walk-up health services—including screening, diagnosis, and treatment—for underserved and rural communities.

Figure 8: Vehicle Type: Community Health Kiosk

Individual Health Transport Vehicle

Mid-sized vehicle that provides health screenings, door-to-door transportation, and, as needed, in-person assistance from an on-board healthcare assistant.

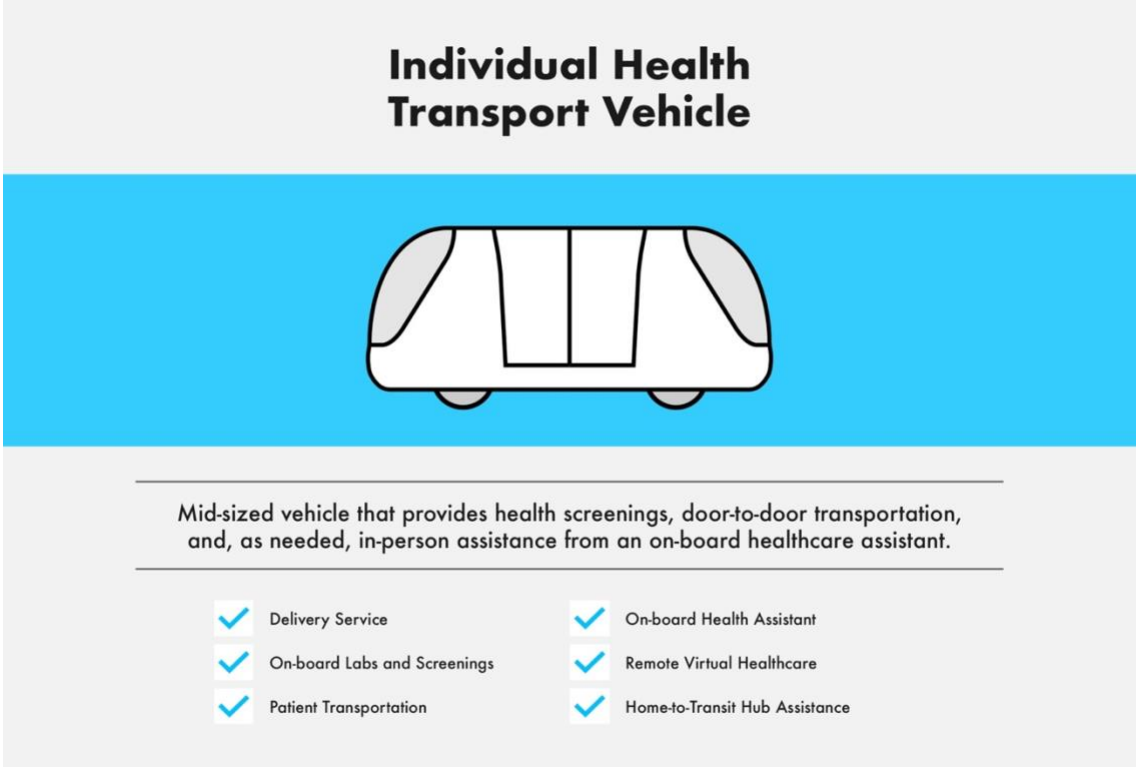

Figure 9: Vehicle Type: Individual Health Transport Vehicle

Shared Health Transport Vehicle

Large vehicle that provides room for shared patient transportation with the same level of on-board service as the individual health transport vehicle.

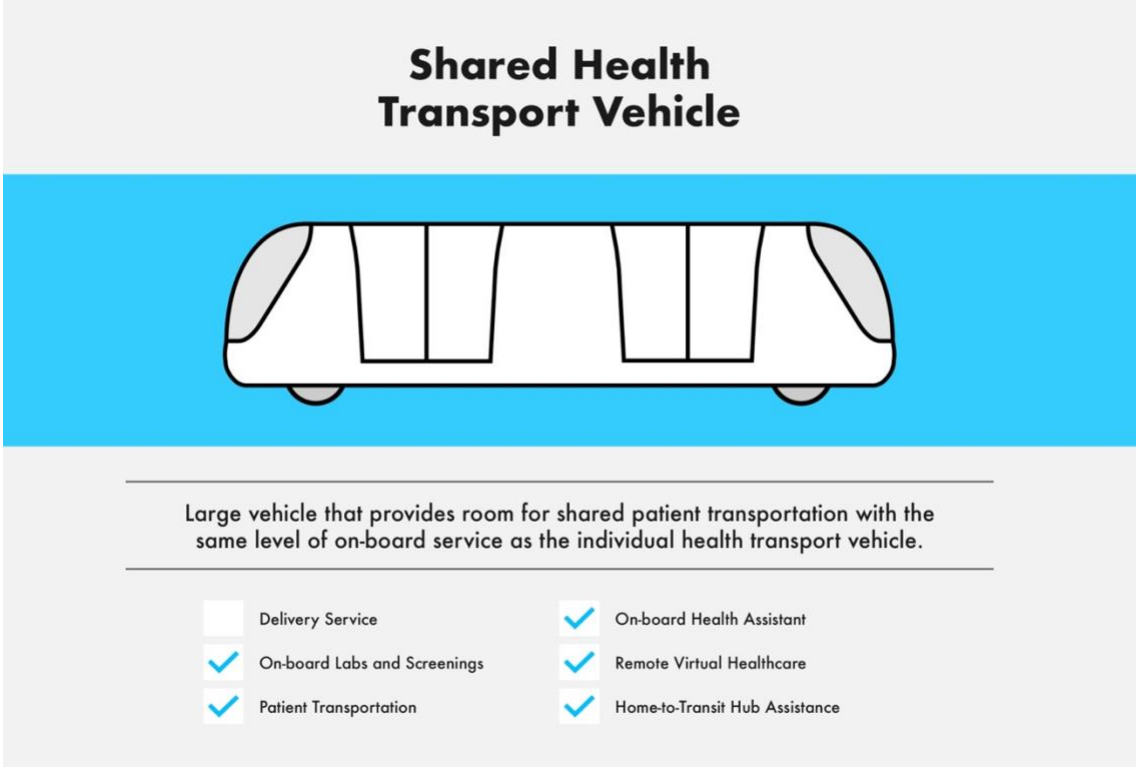

Figure 10: Vehicle Type: Shared Health Transport Vehicle

Services

Building off of the vehicle features and vehicle types, I developed four service concepts to illustrate some of the benefits of each vehicle within a health transportation system grounded in preventative care. This list of service concepts is not meant to be exhaustive of all of the concepts developed during design workshops. Instead, they are examples of four ways of extending healthcare services through the use of autonomous vehicles, particularly for individuals who currently experience limited access to care due to limitations of time, accessibility, and cost. The service concepts are divided into four main areas:

1. Delivery
2. Mobile health
3. Commuter checkups
4. Epidemic control

Within each concept illustration is a diagram of a high-level transportation journey, followed by a brief description of how each would function within the speculative system. The lower right side of each illustration describes a potential target user, the user's primary goal, and the associated benefits that could be achieved through the use of each speculative service. Along the bottom of each illustration is a list of the top three design principles to which each service is tailored.

Delivery—Healthcare Delivery Pod

Individuals with limited mobility or access to affordable transportation options receive store-to-door delivery of essential food, medication, and equipment associated with their medical treatment plans. Delivery of these items is provided through dual-purpose health delivery and transport vehicles with on-board storage and curbside human or robotic delivery assistance.

Potential Target User: Disabled veteran with back pain, a knee injury, and post-traumatic stress disorder who has frequent visits to the hospital for chronic pain.

Goal: Reduce his pain and understand the prescriptions he is taking.

Benefits: Reduced exposure to noise and activity that may aggravate his PTSD; less need to travel when in pain or when unable to drive due to medication; increased access to better nutrition through on-demand grocery delivery.

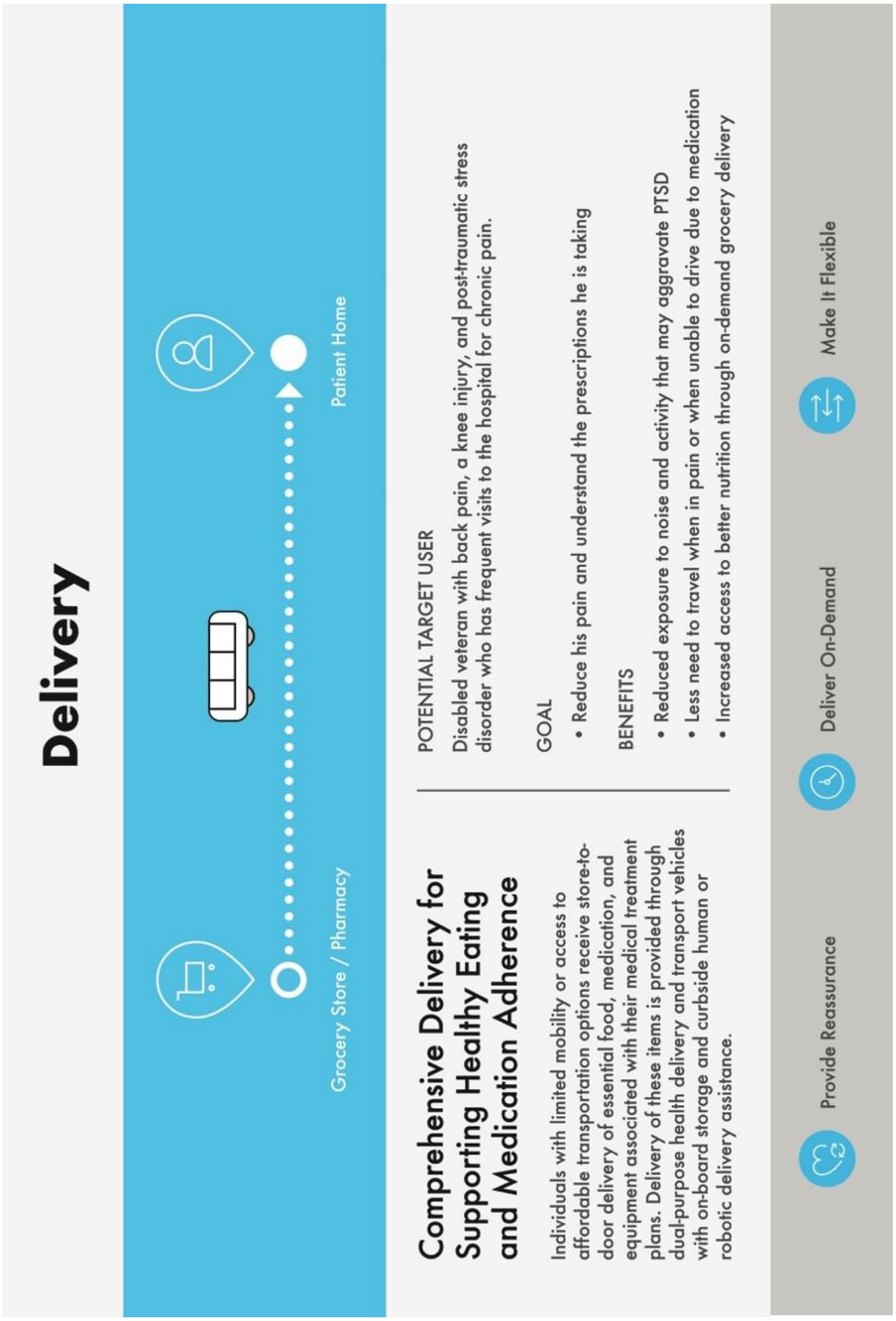

Figure 11: Service Concept: Delivery

Mobile Health—Community Health Kiosk

Smaller communities and metropolitan areas with limited access to healthcare facilities receive tailored, on-demand healthcare services through a dispersed network of rotating health kiosks. These autonomous vehicles provide in-person and virtual access to essential check-ups and preventative care, including vaccinations, immunizations, and well-child visits for mothers and children.

Potential Target User: Young single mother who receives Medicaid benefits and takes her two-year-old son to regular medical checkups and screenings.

Goal: Quickly get to medical appointments and screenings.

Benefits: Less time and money spent getting to regular healthcare appointments; more consistent and flexible appointments and simplified follow-up routine; improved storage space for childcare items including stroller and car seat.

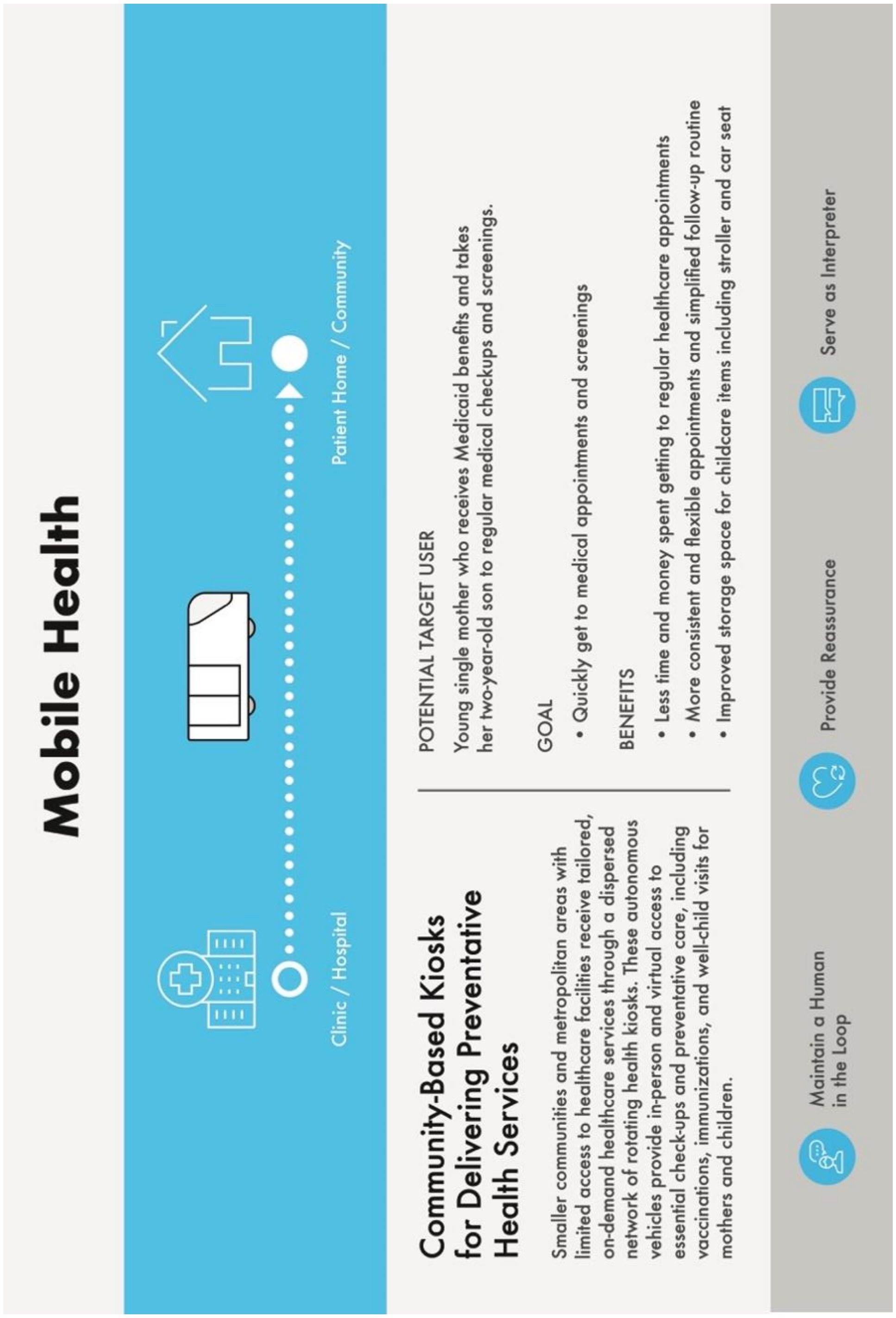

Figure 12: Service Concept: Mobile Health

Commuter Checkups—Individual Health Transport Vehicle

Employers and individual employees gain access to regular in-person and virtual healthcare checkups on an adaptable timeline by taking advantage of regular work commutes. This is accomplished through a distributed set of passive health sensors and monitoring devices embedded in autonomous vehicles used for public and private transit.

Potential Target User: Local government employee who is overweight, prediabetic, and at risk of developing type 2 diabetes.

Goal: Monitor his prediabetes and increase physical activity.

Benefits: Increased access to preventative health screenings and healthcare providers; consistent monitoring for ongoing conditions and annual health checkups; saved time and effort by embedding healthcare in daily work routine.

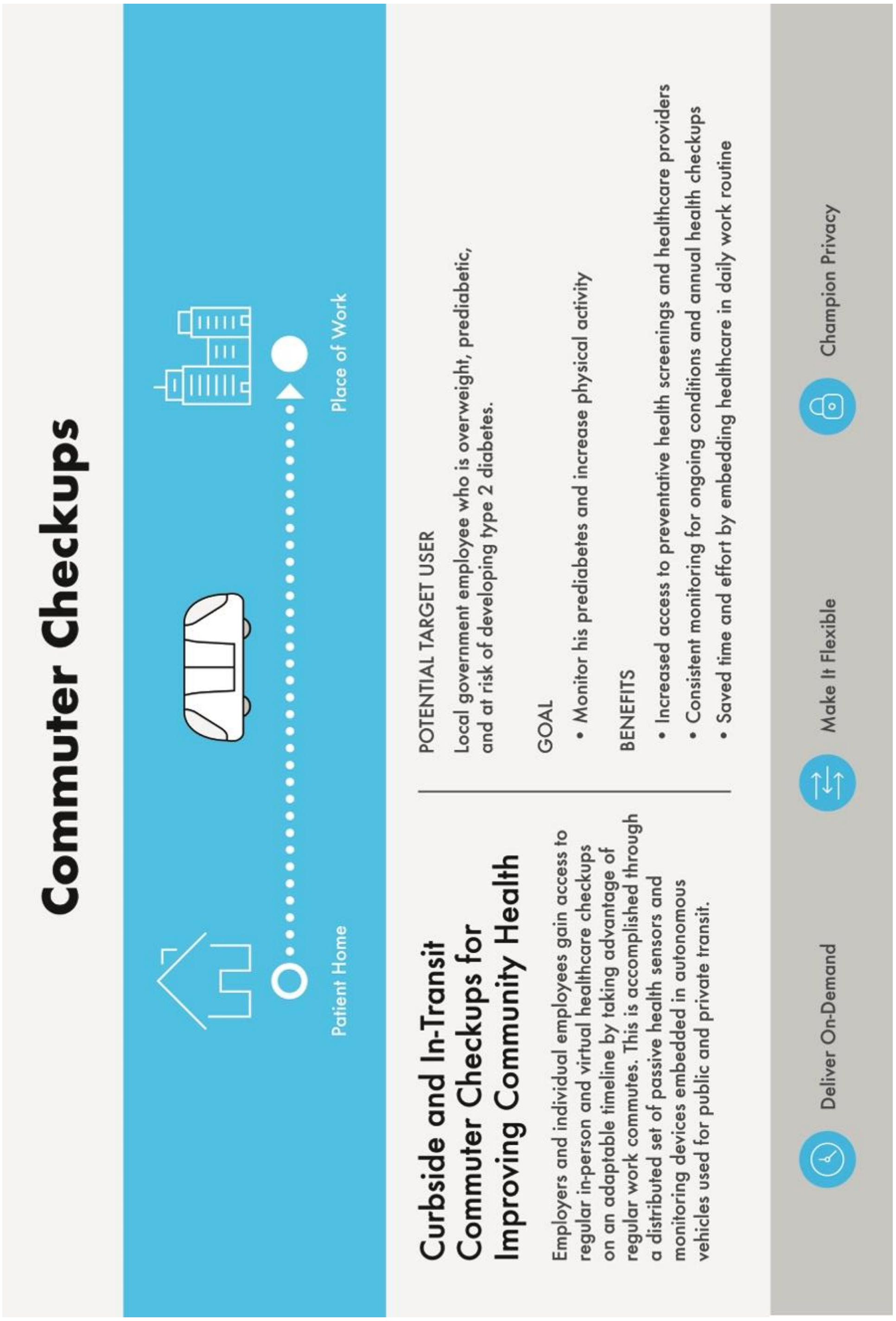

Figure 13: Service Concept: Commuter Checkups

Epidemic Control—Shared Health Transport Vehicle

Communities and the individuals within them who are most susceptible to experiencing severe health conditions during outbreaks receive real-time assistance to neutralize rapidly evolving threats. This is accomplished through anonymous population-level health monitoring and targeted transportation services focused on diagnosis, treatment, and prevention for those most at risk.

Potential Target User: Elderly woman with early onset dementia and vision and mobility limitations who lives with her husband in a rural area.

Goal: To remain healthy and spend more time with her family and friends.

Benefits: Reduced exposure to harmful outbreaks through regular vaccinations; lowered chance of a harmful fall while getting to healthcare services; increased confidence and comfort in healthcare services provided at home.

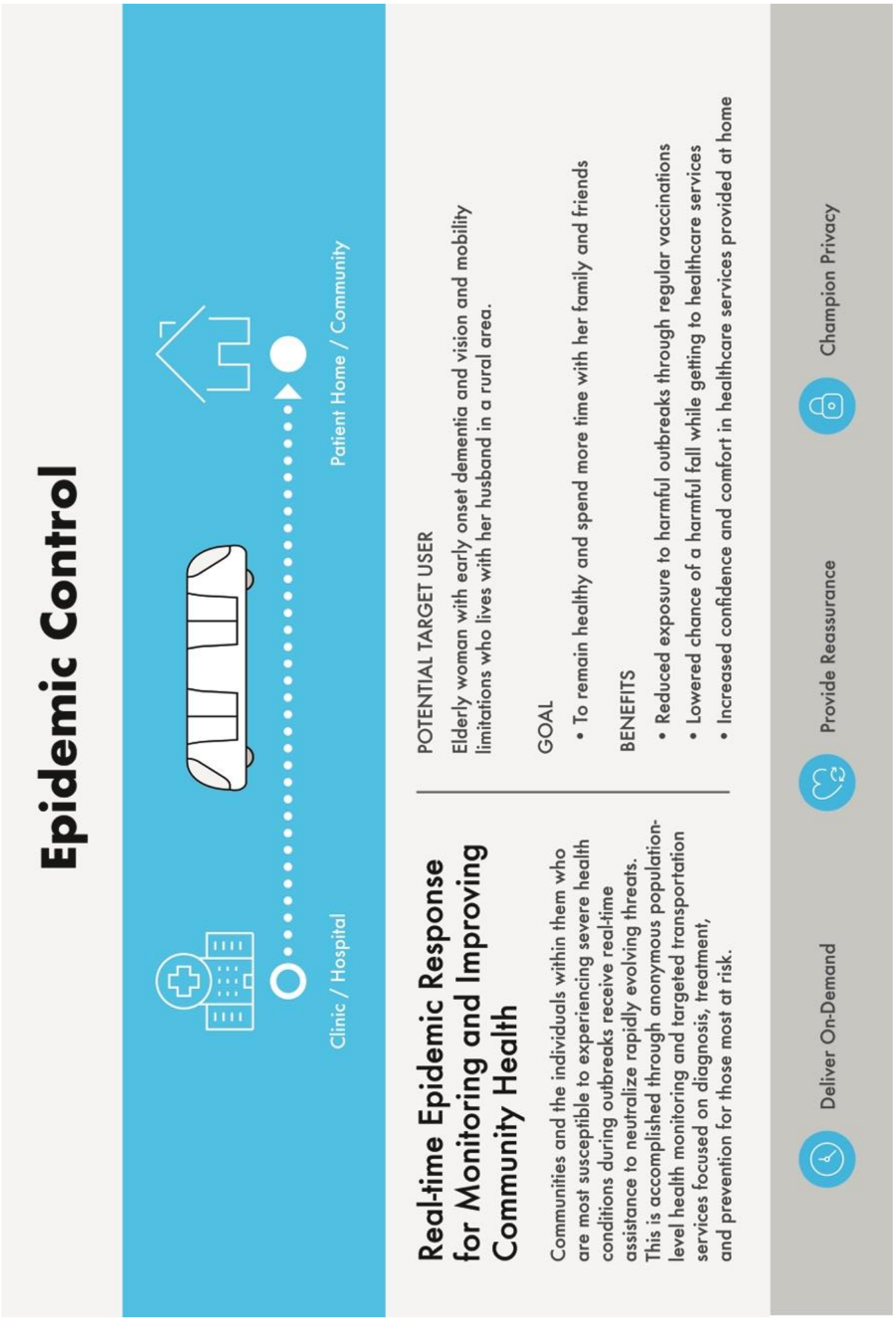

Figure 14: Service Concept: Epidemic Control

Implications

As autonomous transportation evolves, cities and private organizations will have an opportunity to harness autonomous vehicles to improve both individual and community health. But these vehicles will need to be thoughtfully designed in order to successfully deliver healthcare services such as screenings, mental health counseling, and routine check-ups. However, none of these changes are likely without continued attention to real patient needs, especially those related to a complex set of healthcare transportation journeys, which today's transportation system does not fully account for.

The purpose of this research is to serve as a guidepost for local governments, transportation coordinators, hospital systems, insurers, private companies, and others exploring how to best deliver human-centered healthcare transportation. Overall, my aim is to emphasize the need to consider and explore the implications of real human needs during the development of these new technologies, particularly for those who may benefit most from autonomous transportation, such as those with limited mobility, vision, and cognition. So where do we start?

Guidelines for the Development of Autonomous Healthcare Transportation

Listen: Gather more qualitative data on real patient needs, current limitations of healthcare transportation, and potential opportunities for improvement, including vehicle features and ideal opportunities for when and where to deliver healthcare.

Explore: Prototype and iterate on the design of new autonomous vehicle types and services for a broad range of patients, including those with limited mobility, cognition, and vision—and those with limited financial resources, time, or access to healthcare services.

Measure: Quantify the tangible impact of providing autonomous healthcare transportation (e.g. no-show rates, readmission rates, ambulance use, ER visits, preventative screenings, management of chronic conditions, individual- and system-level economic effects, among others).

Develop: Create public and organizational policies that allow autonomous healthcare transportation services and systems to evolve and grow, since true innovations in NEMT may not occur without a concurrent shift in how we value, deliver, and pay for health-related transportation for individuals in need.

Deploy: Deliver healthcare services and needed preventative care—including screenings, vaccinations, and the distribution of health-related items (meals, medical equipment, and prescriptions)—for those with limited access to healthcare.

These steps offer a rough outline of how private organizations and government agencies can begin exploring future opportunities for improved access to healthcare though autonomous vehicles. They are meant to be inspirational in nature, and it is my hope that the insights and design principles contained within this report will serve as a catalyst for others who are starting to design this future.

Endnotes

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